Department of Energy

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MAR 2 5 1996

DOE-0685-96

Mr. James A. Saric, Remedial Project Director
U.S. Environmental Protection Agency
Region V - SRF-5J
77 West Jackson Boulevard
Chicago, Illinois 60604-3590

Mr. Tom Schneider, Project Manager
Ohio Environmental Protection Agency
401 East 5th Street
Dayton, Ohio 45402-2911

Dear Mr. Saric and Mr. Schneider:

SUBMITTAL OF ADDENDUM TO PROJECT SPECIFIC PLAN AND RESPONSE TO COMMENTS ON SOUTHFIELD INJECTION TEST REPORT

Enclosed for your review and approval are responses to comments on the South Field Injection Test Report and an addendum to the Project Specific Work Plan for the injection test. The addendum outlines the plan for an additional injection test in the South Field area. This additional injection test will utilize treated water to determine if the iron plugging problem experienced during the first test will be alleviated by utilizing a treated water source for injection.

As discussed per our telephone conversation on March 22, 1996, the second injection test is scheduled to begin on March 26, 1996. If you have additional questions, please contact Kathleen Nickel at (513) 648-3166, or John Kappa at (513) 648-3149.

Sincerely,

Johnny Reising

Johnny W. Reising
Fernald Remedial Action
Project Manager

FN:Nickel

Enclosure: As Stated

Recycled and Recyclable

cc w/enc:

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ADDENDUM TO THE PROJECT-SPECIFIC PLAN FOR THE SOUTH FIELD INJECTION TEST PHASE II INJECTION TEST WORK PLAN

INTRODUCTION

This Addendum to the Project-Specific Plan for the South Field Injection Test (DOE 1995a) outlines the scope of work for an additional injection test in the South Field area of the Fernald Environmental Management Project (FEMP) which will be referred to as the Phase II Injection Test. Groundwater treated by the FEMP South Plume Interim Treatment (SPIT) system will be injected into the Great Miami Aquifer through a South Field extraction system well. The objective will be to demonstrate that injecting water that has been treated at the SPIT into South Field wells will not create plugging problems. If plugging is not a problem during the Phase II test, a larger demonstration of injection will be undertaken. The quality of the treated water will be similar to the quality of the injection water that will be used in the larger demonstration. The larger field-scale demonstration will be conducted to verify the benefits of injection to the remediation of the Great Miami Aquifer. Funding for Phase II and the larger field-scale test will come from the U.S. Department of Energy's office of Science and Technology Plume Focus Area (EM-50).

The need for this test was identified through an earlier injection test as documented in the South Field Injection Test Report issued in December 1995 (DOE 1995b). That test indicated that injection into the aquifer can be a viable supplement to extraction for remediating the Great Miami Aquifer if plugging problems encountered within the injection well during the test could be eliminated or controlled. During the earlier test, groundwater was pumped from the South Plume area and injected into the South Field area, creating conditions favorable for iron hydroxide precipitate and iron bacteria to work synergistically to plug the screen of the injection well. Plugging of the injection well screen lowers the efficiency of the injection process. The probable cause of the iron plugging has been identified and should be eliminated by injecting water into the aquifer that is more chemically similar to the in situ groundwater; i.e., water treated at the SPIT system is more like in situ South Field groundwater than groundwater from the South Plume area. An additional injection test is needed to verify that the correct cause of the observed plugging has been identified.

A pretest investigation of the water chemistry of the SPIT system effluent and the in situ groundwater at Well 31567 has been conducted and confirms that the chemistry of the two waters are similar in respect to Eh, pH, and iron content. Geochemical modeling was conducted to determine if either carbonate and/or iron precipitation could possibly result from mixing the two water types together. The results of the pretest investigation (presented below) indicate that mixing SPIT system effluent

with in situ groundwater at Well 31567 should not result in plugging problems due to either carbonate or iron precipitation. No other precipitates were predicted to form. Without the precipitation of iron, bacteria that thrives on the precipitation process should not be able to thrive and should not contribute to well screen plugging.

Given the favorable outcome of the pretest analysis, Phase II of the injection test will proceed with actually injecting the SPIT system effluent into Well 31567 for a minimum time period of 72 hours, (4320 minutes). Water levels in Well 31567 will be monitored to determine if plugging of the well screen is occurring. During the earlier injection test, plugging occurred after 10 hours (600 minutes) of injection.

The Phase II test is intended to demonstrate that the iron plugging encountered in the first test resulted from the incompatible chemistries of the injected water and the formation water within the injection well. If results of the Phase II test do not turn out as predicted and lead to the determination that plugging is still a problem, additional tests could be performed. For instance, public water could be injected to determine if potable water would cause a plugging problem. Another alternative would be to modify the FEMP treatment system so as to eliminate the problem.

Because no injection wells have been designed or installed at the FEMP, injection tests need to be conducted in existing extraction wells. The nine wells which were recently installed in the South Field are the only extraction wells that could be used for an injection test at this time. Because treated water coming from the SPIT system will be the source of the injection water, the closest well (31567) was selected as the injection well for the Phase II test. A tap into the SPIT system has been installed and a 4-inch-diameter hose will be used to deliver SPIT system water to Well 31567. A new downcomer, capable of delivering 200 gpm, will be constructed for the test; 200 gpm is the maximum sustained flow rate that the SPIT system will be able to deliver to Well 31567.

No flow streams other than South Plume water will go through the SPIT system during the injection test. The South Plume water going into the SPIT system will have an average total uranium concentration of approximately 17.3 μg/L. The average total uranium concentration of the treated water exiting the system will be approximately 5 μg/L. The SPIT system effluent will be sampled for uranium every 12 hours during the test, with an analytical turnaround time of 24 hours. It is very unlikely that a problem with the system would allow untreated water to by-pass treatment and be

injected into Well 31567. Any problem with the SPIT system would most likely result in a decrease in flow to the injection well. The injection test will be terminated if total uranium concentrations in the injection water rise above 20 μg/L.

Below is some additional information on the nature of the plugging problem followed by an outline of the Phase II testing program. The data management analysis and reporting and health and safety requirements outlined in the Project-Specific Plan for the South Field Injection Test will be followed for the Phase II test. All work will be conducted in accordance with the requirements of the SCQ and RM-0012, Rev. 3 - the Quality Assurance Program at the FEMP. Specific quality items will be reviewed by FERMCO P/QA staff to verify that the quality requirements are adequate and consistent with the assigned quality level. Field quality control will be consistent with guidance provided in the SCQ (DOE 1993).

BACKGROUND

During a previous injection test (October 1995), Great Miami Aquifer groundwater from Wells 3926 and 3927 (the South Plume extraction system) was conveyed to and injected into Well 31550 (in the South Field area). The pumped water was diverted from the South Plume force main using a temporary pipeline that tapped into the force main south of the storm sewer outfall ditch. The Great Miami Aquifer groundwater underwent no treatment before being injected, and was isolated from the atmosphere as it was transported to the South Field. The injection rate into Well 31550 was 300 gpm. After approximately 600 minutes into the test the water level in the injection well began to rise exponentially. A plot of the water level rise in the injection well versus time indicated biological plugging (DOE 1995b).

A subsequent downhole camera survey of the well revealed that portions of the casing were stained orange-red and that a good deal of the surface area of the well screen was covered by an orange-red flocculating substance. Water samples collected from the injection well following the test revealed that only ferric iron was present (no ferrous), and a microscopic analysis of a water sample indicated the presence of an iron bacteria from the genus *Gallionella*.

Water quality sampling in the South Plume indicates that the Great Miami Aquifer in the area of Wells 3926 and 3927 contains approximately 10 mg/L of iron and is relatively reduced with respect to

iron. Water quality sampling in the South Field area around Well 31550 indicates that the groundwater contains approximately .17 mg/L iron and is relatively oxidized with respect to iron.

The conclusion reached from the previous injection test was that Great Miami Aquifer groundwater, which was relatively high in iron and low in dissolved oxygen, was injected into water which was relatively low in iron but high in dissolved oxygen. Mixing of the two water types resulted in the oxidization of ferrous iron into ferric iron. The oxidization reaction released electrons and created an environment in which *Gallionella* iron bacteria thrive. The *Gallionella* iron bacteria served as a catalyst to the precipitation reaction.

Iron bacteria is found almost everywhere, in both water and soil, and is particularly prevalent in the upper midwestern United States. Iron bacteria plugs wells by enzymatically catalyzing the oxidation of ferrous iron to ferric iron and using the energy released from the reaction to promote the growth of thread-like slimes that accumulate large amounts of ferric hydroxide. The ferric iron is drawn onto the mucilaginous slimy sheaths of the bacteria. Precipitation of the ferric iron coupled with the rapid growth of the iron bacteria creates a voluminous material that quickly plugs the screen of the well and the aquifer material surrounding the well bore (Driscoll 1986, pg. 646).

In the natural environment, iron occurs in two different oxidation states, divalent (ferrous) and trivalent (ferric). The conversion of one state to another is achieved through the exchange of electrons. In groundwater, the following reaction is common:

$$2Fe^{+2} + \tfrac{1}{2}O_2 + 2H^+ \rightarrow 2Fe^{+3} + H_2O \qquad (1)$$

The equilibrium is controlled by the partial pressure of oxygen (PO_2) and by the concentration of hydrogen ions (pH). The Eh is related to the PO_2 and pH as defined by the Nernst equation (Krauskopf 1979).

$$Eh = E^0 + \frac{0.059}{n} \times LOG\,(PO_2)^{1/2} + \frac{0.059}{n} \times LOG\,(h^+)^2 \qquad (2)$$

where: E^0 = the overall potential of Equation 1

n = the number of electrons transferred

The oxidation process above (Equation 1) consists of two half cell reactions.

$$2Fe^{+2} \rightarrow 2Fe^{+3} + 2e^{-}, \qquad E^{0} = +.77 \ volts \tag{3}$$

$$2e^{-} + \tfrac{1}{2}O_2 + 2H^{+} \rightarrow H_2O, \qquad E^{0} = -1.23 \ volts \tag{4}$$

The E^0 for Equation 1 calculates out to -0.46 volts, which indicates that the reaction will occur spontaneously as written. Given a near-neutral pH, ferrous iron is stable at an Eh of approximately 130 millivolts (mV) or less relative to the standard hydrogen electrode. At an Eh above 130 mV, ferric iron is stable.

The composition of the groundwater in the Great Miami Aquifer varies with location. Closer to recharge areas (i.e., the South Field and the storm sewer outfall ditch) rain, melted snow and melted ice enters the aquifer. This water contains a relatively high amount of dissolved oxygen and a low amount of iron. In areas of the Great Miami Aquifer that are not close to recharge areas the groundwater reacts with the aquifer material and dissolves iron. Microorganisms deplete the water of oxygen. In the Great Miami Aquifer, oxidizing conditions are found near Paddys Run and in the shallow portions of the saturated material. The dissolved oxygen content decreases with depth and distance from Paddys Run.

The variation in composition of groundwater in the Great Miami Aquifer is revealed by measuring the Eh, pH, and dissolved oxygen content of the groundwater. If groundwater is pumped from the Great Miami Aquifer and injected back into the Great Miami Aquifer, the compatibility of the two waters will determine if iron or calcium precipitation will occur.

PRETEST INVESTIGATION

A groundwater sample was collected from Well 31567 and a water sample was collected from the effluent of the SPIT system. Both water samples were analyzed for the parameters listed in Table A-1. A YSI 600 XL multiparameter water quality monitor attached to a YSI Model 610-D datalogger was used to collect in situ measurements of pH, redox potential, temperature, total dissolved solids, and dissolved oxygen. The redox potential listed in Table A-1 has been corrected to the standard hydrogen electrode.

The data listed in Table A-1 were used to model mixing reactions of the two waters using the EQ3/6 geochemical computer code (PC Version 7.2). EQ3/6 was developed at Lawrence Livermore National Laboratory (Wolery 1992; Wolery and Daveler 1992) for predicting the behavior of metals, radionuclides, and other contaminants in the natural environment. The EQ3/6 computer code is an industry-standard geochemical model that performs solubility and speciation calculations and reaction-path modeling.

For the modeling, SPIT system effluent was mixed with groundwater from Well 31567 under oxidizing conditions (i.e., Eh of 412 to 414 mV over the pH range of 7.0 to 7.3) to evaluate the potential for iron hydroxide and calcite precipitation in the screen and surrounding formation. The model predicted that no precipitate would form under these mixing conditions.

Results for iron hydroxide are shown in Figure A-1 as iron concentration vs. mass fraction of SPIT system effluent. Values of 0 to 1 for the mass fraction of SPIT system effluent correspond to 100 percent groundwater from Well 31567 and 100 percent SPIT system effluent, respectively. An iron concentration equal to one-half the reported detection limit of 100 μg/L was assumed for the SPIT system effluent. The data plotted in Figure A-1 indicate that calculated iron concentrations in the mixture always lie below the solubility curve for $Fe(OH)_3$. Iron hydroxide precipitate will not form unless groundwater iron concentrations rise above the solubility curve.

Conditions needed for the precipitation of calcite are also shown in Figure A-1, which plots the concentration product of calcium and bicarbonate ions as a function of pH and mass fraction of SPIT system effluent. Observed values for the calcium and bicarbonate concentration product lie below the solubility curve for $CaCO_3$, and this indicates the mixture will not precipitate calcite. However, the data do approach the solubility curve near pH 7.3, indicating that if the pH of the SPIT system effluent is greater than 7.3, calcite precipitation is possible (but not probable according to the geochemical analyses performed) as the mixture approaches 100 percent SPIT system effluent. During the test this process will be monitored closely by tracking pH and water level changes within the injection well.

PHASE II INJECTION TEST PROGRAM

Phase II will consist of the following activities:

1. Collect a water sample from Well 31567 and the SPIT system effluent and analyze for iron bacteria and the parameters listed in Table A-2. The iron bacteria analysis will be used to document if *Gallionella* is present in either Well 31567 or the SPIT system effluent prior to the start of injection. Measurements of the other parameters will be used to document if the water quality of the groundwater or SPIT system effluent has changed since the groundwater sample for the pretest investigation was collected.

2. Conduct a downhole camera survey of Well 31567 before the start of the test to document whether or not any openings in the screen appear to be plugged.

3. Monitor water levels in Wells 31567, 2065 and 3065 for 7 days before injection. Water level measurements will be collected every hour using in situ transducers and dataloggers. The water level data will be used to establish the regional trend of the aquifer prior to the start of the test. Water level changes measured in Wells 2065 and 3065 during the injection test will need to be corrected to the regional trend established just before the injection began.

4. Monitor water quality in the SPIT system effluent and Wells 31567, 2065, and 3065 for 3 days before injection. Water quality measurements (pH, Eh, temperature, specific conductance, and dissolved oxygen) will be collected at least once a day using downhole multiparameter water quality monitors and dataloggers. Water quality data collected before the start of the injection test will document whether or not water quality conditions are stable or changing.

   Note: Downhole water quality monitors and dataloggers will either be YSI 600 XL monitors with YSI Model 610 D dataloggers or Hydrolab ™ H2OG Water Quality Multiprobes with Hydrolab ™ Surveyor 3 display loggers. Operators of these instruments will be trained and qualified to operate the instruments they are using, or will be closely supervised by someone who is trained and qualified to operate the instruments. These instruments will be operated according to the manufacturers' recommendations and the operators' manual. Calibration requirements contained within the operations manual will be met.

5. Conduct a slug test in Well 31567. Data collected during the slug test will be used to establish a baseline of how easily water could be transmitted through the screen prior to injection.

6. Inject water at a rate of 200 gpm from the SPIT system into Well 31567 for a minimum of 72 hours.

   - Monitor water level changes in Wells 31567, 2065 and 3065 using in situ transducers and dataloggers operating in a test mode.

   - Monitor water quality changes in the SPIT system water and in Well 31567.

7. Conduct a velocity profile measurement of Injection Well 31567 using a spinner tool to learn more about the way the aquifer receives injected water. This was an objective from the Phase I test that was not met due to equipment failure.

8. Stop injection and monitor water level recovery by stepping the datalogger program. Recovery data will be used to indicate if plugging of the screen has occurred. Rapid recovery should occur if the screen is not plugged.

9. Collect a water sample from Well 31567 and analyze for the list of parameters listed in Table A-2. Data will be used to establish if preinjection water quality has changed due to the injection.

10. Conduct a camera survey of Well 31567 after injection is completed. The camera survey will provide physical evidence as to whether or not the injection caused the well screen to plug.

11. Conduct a slug test in Well 31567. Data collected will be compared against test data collected before the start of the injection test to document changes in the efficiency of the screen resulting from the injection.

REFERENCES

Driscoll, F.G., 1986, Groundwater and Wells, 2nd ed., Johnson Division, St. Paul, MN.

Krauskopf, 1979, Introduction to Geochemistry, 2nd edition, McGraw Hill Book Co., New York, NY.

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Wolery, T.J., 1992, "EQ3NR, A Computer Program for Geochemical Aqueous Speciation-Solubility Calculations: Theoretical Manual, User's Guide, and Related Documentation (Version 7.0)," UCRL-MA-110662 PT III, Lawrence Livermore National Laboratory, Livermore, CA.

Wolery, T.J. and S.A. Daveler, 1992, "EQ6, A Computer Program for Reaction Path Modeling of Geochemical Systems: Theoretical Manual, User's Guide, and Related Documentation (Version 7.0)," UCRL-MA-110662 PT VI, Lawrence Livermore National Laboratory, Livermore, CA.

TABLE A-1

PHASE II INJECTION TEST, PRETEST INVESTIGATION
WATER QUALITY TEST RESULTS

Analyte	Sample from Well 31567	Duplicate from Well 31567	SPIT Effluent	Detection Limits
Aluminum	ND	ND	ND	200 μg/L
Calcium	91780 μg/L	90300 μg/L	88940 μg/L	NA
Iron	123.4 μg/L	165 μg/L	ND	100 μg/L
Magnesium	23270 μg/L	23110 μg/L	22870 μg/L	NA
Manganese	355 μg/L	363 μg/L	133 μg/L	NA
Potassium	ND	ND	ND	5000 μg/L
Silicon	3632 μg/L	3841 μg/L	3862 μg/L	NA
Sodium	11020 μg/L	11450 μg/L	12420 μg/L	NA
Chloride	24.2 mg/L	24.2 mg/L	27.9 mg/L	NA
Sulfate	78.5 mg/L	81.4 mg/L	78.8 mg/L	NA
TDS	370 mg/L	402 mg/L	424 mg/L	NA
Alkalinity	ND	ND	ND	.01 N
Fluoride	0.17 mg/L	0.17 mg/L	0.20 mg/L	NA
Nitrate-nitrogen	ND	ND	ND	0.1 mg/L
Solids	26 mg/L	28 mg/L	ND	2 mg/L
Ammonia	ND	ND	ND	0.1 mg/L
Phosphate (total)	ND	ND	ND	<0.1 mg/L
Uranium	26 μg/L	26 μg/L	0.2 μg/L	NA
Carbonate	ND	ND	ND	2000 μg/L
Bi/carbonate	234 mg/L	236 mg/L	250 mg/L	NA
pH (field)	7		7.28	NA
Redox (field)	411.7 mV		414.2 mV	NA
Temperature (field)	11.36°C		11.60°C	NA
TDS	.49 g/L		.42 g/L	NA
Dissolved oxygen	.36 mg/L		.28 mg/L	NA

ND = non detect
NA = not applicable

TABLE A-2

PHASE II INJECTION TEST ANALYTICAL PROGRAM
CHEMICAL & RADIOLOGICAL PARAMETERS

Parameter	Holding Time	Chemical Preservative	Container(s) Required	ASL
Iron bacteria o	24 hrs	Na_2S Na_2SO_4 Cool to 4°C	1 - 1 liter glass 1 - 500 ml glass	E
Metals (filtered) Al,Ca,Fe,Mg,Mn,K,Si,Na	6 months	HNO_3, pH < 2	1 - 1 Liter plastic	B
Alkalinity/Fluoride/TSS Nitrate as Nitrogen *	48 hrs	Cool to 4°C	1 - 1 Liter plastic	B
Carbonate/Bi-carbonate Table 41a ⊗	14 days	Cool to 4°C	1 - 1 Liter plastic	B
Chloride/Sulfate/TDS ♀	7 days	Cool to 4°C	1 - 1 Liter plastic	B
Ammonia	28 days	H_2SO_4, pH < 2 Cool to 4°C	1 - 500 ml plastic	B
Phosphate (Total) ♀	28 days	H_2SO_4, pH < 2 Cool to 4°C	1 - 500 ml plastic	B
Total uranium ★	6 months	HNO_3, pH < 2	1 - 250 ml plastic	B

NOTE: Field QC samples shall be performed using the following frequencies:

No field QC samples will be collected for Iron Bacteria per customer request.

Rinsate - 1 in 20 sampling point.
Field Blank - 1 in 20 sampling point.
Duplicate - 1 per sampling point.

♀ Sample to be analyzed at Water Treatment Plant, ensure SPL receives a copy of the CoC.
⊗ Sample to be analyzed by TCT laboratory.
o Sample to be analyzed by Applied Microbial Technology.

The remaining samples will be delivered to SPL.

Special instructions on Chain of Custody

* *Nitrate sample has 48 hour hold time.*

★ *Total uranium analyzed by KPA at LLEM.*

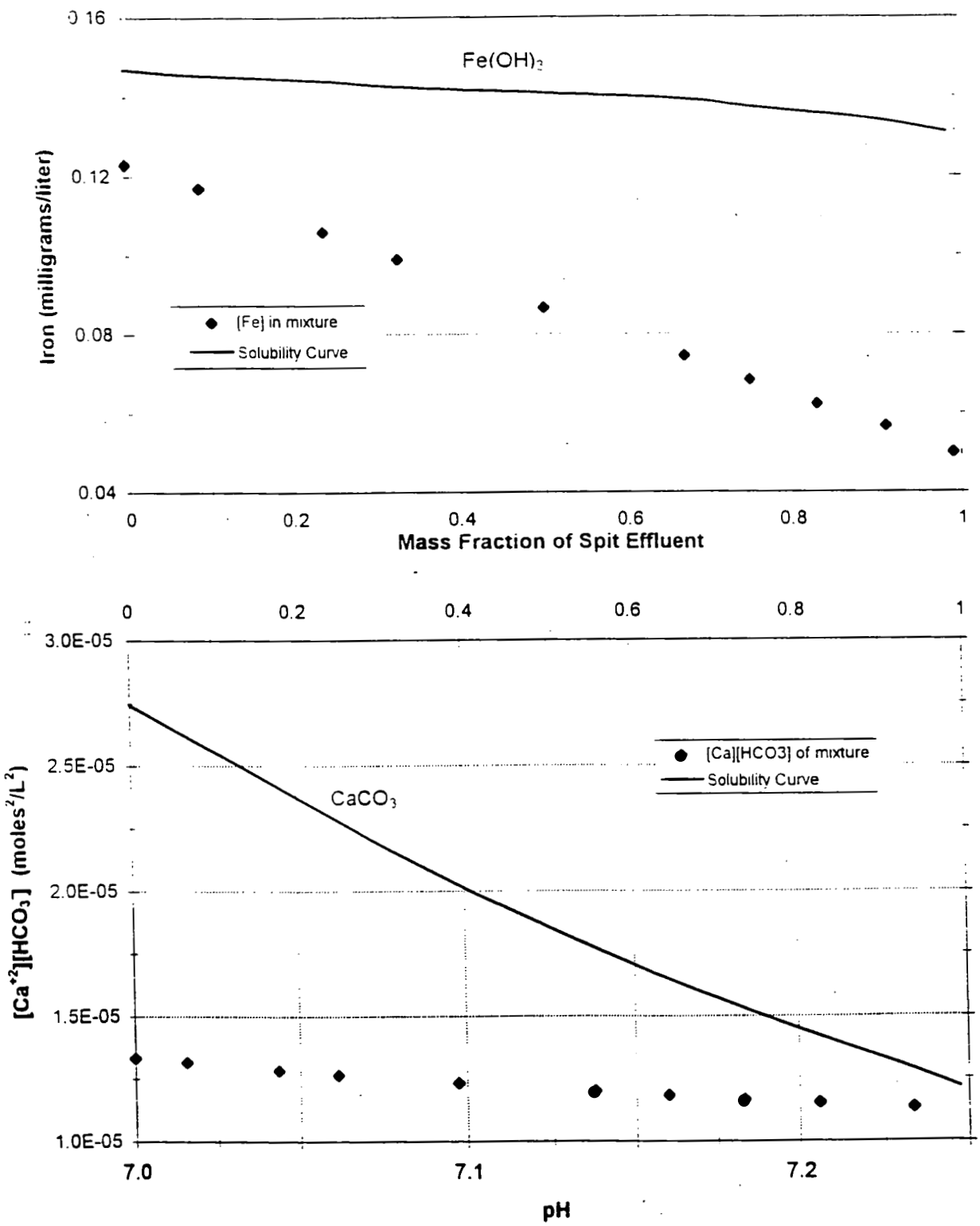

FIGURE A-1 GEOCHEMICAL MODELING RESULTS FOR IRON HYDROXIDE AND CALCITE

SCHEDULE FOR PHASE II INJECTION TEST

Tues. March 12, 1996
- * Install water quality probe in SPIT Effluent line and begin monitoring water quality. A minimum of one measurement per day should be collected.
- • Collect groundwater samples from Wells 31567, 2065, and 3065.
- * Conduct a downhole camera survey of well 31567.

Wed. March 13, 1996
- * Install transducers and water quality probes into wells 31567-In, 31567-Out, 2065, and 3065. (Set for every hour).

Thu. March 14, 1996 to Thu. March 21, 1996
- * Conduct pre-test monitoring of water levels and water quality.

Mon. March 25, 1996
- * Conduct slug tests
- * Run a system check

Tue. March 26, 1996
- * Begin Injection Test
- * Conduct velocity profile

Wed. March 27, 1996
- * Monitor progress of Injection Test
- * Conduct a velocity profile

Thu. March 28, 1996
- * Monitor progress of Injection Test
- * Conduct a velocity profile

Fri. March 29, 1996
- * Stop injection test
- * Monitor recovery
- * Collect water sample from well 31567 and SPIT Effluent

Mon. April 01, 1996
- * Conduct a camera survey of well 31567
- * Conduct slug tests